Space Technology Research Grants

# Exploration of Extreme Terrain Using a Polyhedral Rover

Completed Technology Project (2016 - 2020)

## Project Introduction

Exploring celestial bodies with extreme terrains in our solar system, like Mars, Europa, Enceladus, and asteroids, are of great importance to NASA because these bodies are often rich with scientific data (TA 4.2.1, TA 4.2.4). In the past, many bodies have been inaccessible to exploration missions because current rover technology is not effective on these terrains. To address this problem, my research will focus on developing an autonomous polyhedral rover that has many advantages over current rover technology. It has three main features that make it especially effective for navigating extreme terrains. First, the rover will use an internal momentum control system to roll from side to side for locomotion. The momentum control system will never come in contact with the environment, eliminating the risk of actuator failure from terrain interaction, thus increasing the reliability of the rover. Second, the momentum control system will generate enough torque to quickly navigate obstacles like rocks and steep inclines. Third, the rover will have spikes or gripping pads on the corners of the chassis, allowing it to get traction on almost any surface. There are 4 stages to the completion of the rover: Stage 1: Optimize momentum control system arrays with respect to torque output, power usage, and mass. Create generalized control algorithms for the optimized arrays, taking into account the power usage and dynamics of the momentum control system and the dynamics of the chassis (TRL 1-2). Stage 2: Create a path planning algorithm that is optimized for power generation and usage, and travel time. This algorithm will use the control algorithm created in Stage 1 to model the power usage and dynamics of the momentum control system. This algorithm will model the traction between the chassis spikes and the terrain. It will also model the rover's power generation according to the sun's position and the shading of the solar cells. This algorithm will be generalized to various polyhedral chassis shapes and momentum control system array configurations (TRL 1-2). Stage 3: Simulate the performance of various combinations of chassis shapes and momentum control system arrays using the path planning algorithm created in Stage 2 (TRL 3). Stage 4: Choose the best performing rover for a selected mission using the simulation in Stage 3. Build the selected rover and compare its actual performance to the simulated performance. I will use Cornell University's Space System Design Studio for testing and fabrication (TRL 3-7). The final rover can explore many celestial bodies in our solar system. The power- and torque-efficient internal momentum control system and the novel chassis design make this rover reliable, power-efficient and terrain-adaptable, allowing for a long mission lifetime. The rover could explore previously unexplored areas, like the surface of Europa and Enceladus. It could also explore currently inaccessible valleys, crags, and rock beds on Mars. Exploring these areas could help discover water content, microbes, mineral content, among others. The rover would also be ideal for supporting manned missions, like the planned mission to Mars in the 2030s and the mission to an asteroid in 2025. It could travel to the celestial body ahead of time and explore potential landing zones to ensure they are safe. After the arrival of the mission, the


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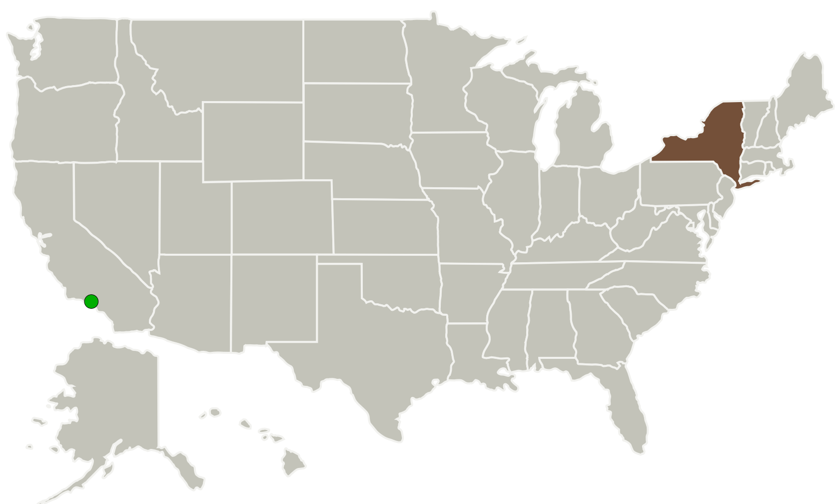
rover could carry supplies for the astronauts and help with exploration. Additionally, my work could help the development of polyhedral rovers for future missions. I will generalize all of the algorithms and simulations to other chassis shape, momentum control array configurations, and terrains, allowing future projects to quickly iterate through rover designs to select the optimal robot for a specific mission.

### Anticipated Benefits

Development of a reliable, power-efficient and terrain-adaptable autonomous polyhedral rover will enable exploration of previously unexplored areas of celestial bodies in our solar system such as the surface of Europa or Enceladus and the currently inaccessible valleys, crags, and rock beds on Mars. Exploring these areas could help discover water content, microbes, mineral content, among others. The rover would also be ideal for supporting manned missions, like the planned mission to Mars in the 2030s and the mission to an asteroid in 2025. It could travel to the celestial body ahead of time and explore potential landing zones to ensure they are safe. After the arrival of the mission, the rover could carry supplies for the astronauts and help with exploration.

### Primary U.S. Work Locations and Key Partners



## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

Cornell University

**Responsible Program:**

Space Technology Research Grants

## Project Management

**Program Director:**

Claudia M Meyer

**Program Manager:**

Hung D Nguyen

**Principal Investigator:**

Mason A Peck

**Co-Investigator:**

David Sawyer Elliott

| **Organizations Performing Work** | **Role** | **Type** | **Location** |
|---|---|---|---|
| Cornell University | Lead Organization | Academia | Ithaca, New York |
| Jet Propulsion Laboratory(JPL) | Supporting Organization | NASA Center | Pasadena, California |

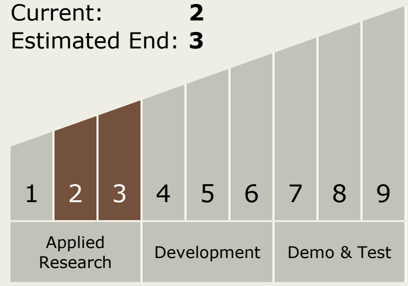
| **Primary U.S. Work Locations** |
|---|
| New York |

**Project Website:**

https://www.nasa.gov/strg#.VQb6T0jJzyE

## Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**




## Technology Areas

**Primary:**

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.7 Guidance, Navigation and Control (GN&C) for EDL

## Target Destinations

The Moon, Mars, Others Inside the Solar System